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INTERLABORATORY STUDY OF THE CONCRETE PRISM EXPANSION TEST FOR THE ALKALI-CARBONATE REACTION

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INTERLABORATORY STUDY OF THE CONCRETE PRISM EXPANSION TEST FOR THE ALKALI-CARBONATE REACTION

ABSTRACT

In Canada, the concrete prism expansion test is used for measuring expansion due to potentially alkali-carbonate reactive concrete aggregate. Three (3) concrete prisms about 75 x 75 x 400 mm, are made with the suspect aggregate and 310 kg m^3 cement with an alkali content of not more than 1.0% Na_2O equivalent. The prisms are stored in a moist room at 23 C. In order to judge the quality of individual test results it is necessary to know the precision of the test method. This report describes a study of the precision of this test sponsored by Canadian Standards Association Committees A5 and A23. Twelve laboratories participated in this study. They tested three aggregates of known field performance: non-expansive, mildly expansive and highly expansive (0.008%, 0.030% and 0.077% expansion respectively at 1-year). This study found that for expansion less than 0.014%, results of two properly conducted tests in different laboratories, on the same aggregate, should not differ from each other by more than 0.009%. For expansion greater than 0.014%, the results should not differ by more than 65% of their average. For expansion less than 0.02%, the range (difference between highest and lowest) of three individual prism measurements used in calculating a test result should not exceed 0.008%. For expansion greater than 0.02%, the range should not exceed 40% of the average of the three.

KEYWORDS:

concretes; tests; alkalies; carbonate; reaction; expansion; statistics; aggregates, alkali-carbonate rock reaction.

INTRODUCTION

The alkali-carbonate rock reaction was first described by Swenson in 1957. This reaction can cause excessive expansion and cracking of portland cement concrete within three years. It occurs with quarried sedimentary dolomitic limestones with moderate to high clay contents. Typical expansive carbonates of this type, in Ontario, have CaO:MgO ratios of 5 to 10, alumina (Al_2O_3) contents of 2 to 3%, and insoluble residues of 10 to 15% (Rogers, 1986). Higher cement alkali contents result in increased expansion. The pessimum proportion is 100%. Expansion of concrete is caused by swelling of individual coarse aggregate particles. This is thought to be due to adsorption of water on previously dry clay surfaces in the rock (Gillott, 1975).

There are four procedures for testing aggregate for this reaction:

1. Petrographic examination of thin sections of the rock, to observe the characteristic reactive texture of euhedral dolomite rhombs in a clayey, micritic matrix.

2. The rock-cylinder expansion test that measures expansion when stored in alkali solutions (ASTM C 586).

3. A quick chemical test, used in Ontario, that identifies those aggregates that have a bulk composition corresponding to known reactive carbonate aggregates (Rogers, 1986).

4. The concrete prism expansion test, normally used as the specification method to measure expansion of concrete containing aggregate recognized as being potentially reactive using the other tests (CSA A23.2 - 14A).

CONCRETE PRISM EXPANSION TEST

In early studies of the alkali-carbonate reaction, the mortar bar expansion test gave insufficient expansion (Swenson, 1957). Swenson developed a concrete prism expansion test that has been adopted by the Canadian Standards Association (CSA A23.2 - 14A). Three concrete prisms (75 x 75 x 350 mm to 120 x 120 x 450 mm) are made using the suspect coarse aggregate in a mixture with 310 kg m^3 of normal portland cement and a non-reactive fine aggregate. The alkali content of the cement should normally be 0.9 ± 0.1% Na_2O. Sodium hydroxide is added to the mixture to give a final equivalent alkali content of 1.0% Na_2O by mass of cement or the highest cement alkali content likely to be encountered. On demoulding, the prisms are stored in a moist room and expansion measured periodically and reported as a percent change in initial length. The average of the three prism expansions is reported as the final test result.

The 1977 Canadian Standard recommended (CSA A23.1, Appendix B) in a non-mandatory appendix, that expansions in excess of 0.02% at 84 days be considered harmful for concrete exposed to moist conditions. Expansions in excess of 0.03% at any age were also considered to indicate potentially deleterious reactivity. More recent data have shown that expansions in excess of 0.025% at 1-year, when tested with 1.25% Na_2O equivalent alkalies by mass of cement, are potentially harmful for concrete exposed to a moist environment with sodium chloride (Rogers, 1986).

Purpose of Study

The primary purpose of this study was to gain data to formulate a multi-laboratory precision statement over a range of expansion values for the concrete prism expansion test. A secondary purpose was to gain information about possible sources of variation in the test. A third purpose was to gain information on appropriate expansion limits, by using aggregates of known field performance.

Design

The ASTM Practice for conducting interlaboratory test programs to determine the precision of test methods was followed as far as possible (ASTM C 802-80). ASTM C 802 recommends that, for 10 to 15 participating laboratories, at least three replicates of each material are tested by each laboratory so that n is equal to or greater than 30. In this study, such a requirement would have resulted in an unacceptable amount of work and high cost or alternatively resulted in a reduction in the range of material properties that could be investigated. The ASTM practice recommends a minimum of three materials. In this test, there is more than one test result for each material. Expansion results are obtained at various ages. Expansion at each age is amenable to statistical treatment for calculation of variance. It was decided that the large amount of data at different ages for each material would compensate for not testing replicate materials. This design also precluded estimates of within-laboratory precision.

The study was separated into three parts as follows:

Part 1 - Mixtures 1, 2 and 3.
Three different coarse aggregates of different expansive properties were tested according to CSA A23.2 - 14A. Each laboratory tested each coarse aggregate using its own standard fine aggregate and cement meeting the requirements of the test procedure. If necessary, each laboratory adjusted the alkali content of each mixture to 1.0% Na_2O equivalent by the addition of NaOH to the mixing water. The properties and field performance of the coarse aggregates are shown in Table 1.

Part 2 - Mixture 4.
The mildly expansive aggregate (Part 1, Mixture 2) was tested. Samples of the fine aggregate and cement were supplied by the co-ordinating laboratory. The cement had an equivalent alkali content of 1.1 % Na_2O.

Part 3 - Mixtures 5, 6 and 7

The coordinating laboratory made a number of concrete prisms using the same coarse aggregates as used in Part 1. The prisms were randomized and shipped to seven participating laboratories on demoulding. Each laboratory measured the initial length on the Monday following receipt and stored the prisms in its moist room and measured length change at regular intervals.

Laboratories

Twelve experienced concrete testing laboratories participated in Parts 1 and 2, ten in Canada and two in the U.S.A. The laboratories are designated by the letters A to L. Four of the laboratories (F,G,I,J), had no previous experience with this test method.

Seven Ontario laboratories participated in Part 3. The other laboratories did not take part because of the difficulty of shipping and the possibility of damage to the concrete prisms.

Materials

Three coarse aggregates (4.75 - 19 mm) were chosen from different levels of the McLeod Quarry near Cornwall, Ontario, Canada (Table 1). The rock in this quarry is horizontally bedded, Middle Ordovician limestone and dolomitic limestone with occasional dolostone interbeds. The rock is in the Lower Gull River Formation of Black River age. Three 60-tonne stockpiles from different levels in the quarry were established by the quarry operator.

Sixty-five canvas bags, each of about 30 kg capacity, were filled from each stockpile for mixtures 1, 2, 3 and 4. The bags were taken to the coordinating laboratory, the contents oven dried and assigned randomly to each of the twelve laboratories. No attempt was made to grade or split the bulk material, the reason being, that this rarely occurred in normal practice. "Precision estimates for inclusion in a test method must be obtained under conditions...that are representative of the situations in which the test method will be used in practice" (ASTM C 802-80).

For mixture 4, 36 bags of the coordinating laboratory's standard fine aggregate were assigned randomly to the twelve laboratories. Twelve bags of Type 10 cement were also assigned randomly to the laboratories. Each laboratory received 600 kg of materials for Parts 1 and 2.

For Part 3, 300 kg of coarse aggregate were taken from each of the stockpiles used in Part 1. This aggregate was oven dried, graded and used, together with a standard fine aggregate and cement to make the concrete prisms.

Reporting Mixture Data and Results

Forms were sent to each laboratory to record data on equipment used and mixture proportions and properties. Tables 1 to 6 (Appendix A) show summaries of this data. Forms were also sent to each laboratory to record and report expansion measurements at 28, 56, 84, 112, 168, 275 days and 1 year.

RESULTS

PART 1 AND 2, MIXTURES 1 - 4

Expansion data are shown in Tables 2 to 5. Figure 1 shows the average expansion of each mix. The statistical treatment of the data followed that described in ASTM C 802 except for determination of within-laboratory precision which was omitted from the initial design for reasons of cost.

A number of laboratories' data were omitted from inclusion in the final analysis because the results were considered outliers to the population. A test was made for the presence of interactions between laboratories and materials. This was done by a plot of expansion values of the various materials reported by each laboratory (ASTM C 802 para. 8.2.3). Generally, similar patterns of change were noted from material to material by each laboratory. Some laboratories showed a different pattern from the majority. Laboratories F and J usually gave high values. Laboratory G rated the materials in a different order and Laboratory I usually gave low or erratic results. In these laboratories there must have been some variation causing these discrepancies. These laboratories (F,G,I and J) had never previously performed this test and while they were experienced concrete testing laboratories, nevertheless lacked experience with this procedure. All laboratories that had prior experience rated the materials in the same order and obtained broadly similar data. Not all the data reported by laboratories F, G, I and J were rejected. Individual data were usually rejected based on their being more than three standard deviations from the mean. Youdens (1967) scatter diagram technique was also used for recognizing obvious outliers to the general population (Figure 2). Figures 3, 4 and 5 show the mean and range in values for mixes 2, 3 and 4, together with outliers.

Laboratory J subsequently reported that parts of their moist room were insufficiently wet. To correct this condition, they installed more water mist nozzles. This may account for the low expansion exhibited by some of their prisms (mixture 3), but would not logically account for the high expansion shown by other prisms (mixtures 1, 5).

Multi-Laboratory Precision

Following the rejection of outlying data, the coefficient of variation and standard deviation at each age was plotted against expansion (Figures 6 and 7). This gave information about the best way to formulate a precision statement. In Figure 6, it can be seen that the coefficient of variation was high and variable for expansions less than about 0.014%. For expansions greater than 0.014%, the coefficient of variation was relatively low and stable (average 23%). Figure 7 shows that the standard deviation increased progressively with increase in mean expansion, but did not decrease to zero at low expansion values. For expansion less than 0.014%, the pooled standard deviation was 0.0032%. These results can be formulated into a precision statement, as defined by ASTM C 670, as follows:

Multi-laboratory Precision (average expansion less than 0.014%)- The multi-laboratory standard deviation of a single test result (mean of measurements on three prisms) for average expansions less than 0.014% has been found to be 0.0032%. Therefore, results of two properly conducted tests in different laboratories on the same aggregate should not differ by more than 0.009%.

Multi-laboratory Precision (Average Expansion Greater than 0.014%) - The multi-laboratory coefficient of variation of a single test result (mean of measurements on three prisms) for average expansions greater than 0.014% has been found to be 23%. Therefore, results of two properly conducted tests in different laboratories on the same aggregate should not differ from each other by more than 65% of their average.

Range Within a Laboratory

Using the individual prism measurements, it has been possible to formulate a statement about the expected range in values obtained with three prisms in a single laboratory. This is not the same as within-laboratory precision. It is useful, however, in seeing whether the range in individual values used to calculate a single test result is extraordinarily wide and therefore suspect.

Laboratory variances were calculated from the individual prism expansion data reported by each laboratory for each material at each age. These variances were then pooled and standard deviations and coefficient of variance calculated. A graphical analysis of these data showed that using a pooled standard deviation (0.0025%) for expansion values less than 0.02% and an average coefficient of variation (12%) for values greater than 0.02% gave the most accurate picture of the range that was encountered. Multiplying the standard deviation and coefficient of variation by 3.3, since three values are used to calculate a single test result (ASTM C 670, para. 3.2.2.) gave a statement about expected range as follows:

Range for a single test result (average expansion less than 0.02%) - For average (mean of three prisms) expansions of less than 0.02%, the multi-specimen, single operator standard deviation has been found to be 0.0025%. The range (difference between highest and lowest) of the three individual prism measurements used in calculating a test result should not exceed 0.008%.

Range for a single test result (average expansion greater than 0.02%) - For average (mean of three prisms) expansions of more than 0.02%, the multi-specimen, single operator coefficient of variation has been found to be 12%. The range (difference between highest and lowest) of the three individual prism measurements used in calculating a test result should not exceed 40% of the average of the three.

PART 3, MIXTURES 5 - 7

Expansion data for part 3 is shown in Tables 6-9. Figure 1 shows the average expansion of each mixture. The expansion was generally slightly less than for the corresponding mixtures with the same aggregates, tested in Part 1 (Mixtures 1 - 3). The statistical treatment of data and outliers was identical to that for Parts 1 and 2.

Outliers

An analysis for interactions between laboratories and materials was conducted by plotting expansion values for the various materials reported by each laboratory (ASTM C 802 para. 8.2.3.). Similar values and patterns of change were found for the laboratories with prior experience with this test (A.B.C.D.). Those laboratories that had no previous experience (F, I and J) generally reported high values. The high values reported by lab I were in marked contrast to the low values reported by this laboratory for mixtures 1 - 4. Since the concrete prisms, all made by lab A, had been randomly assigned to each laboratory, there was a low probability that laboratories F, I and J had received biased samples. There must have been some variation of the storage or measuring procedure causing these abnormal values. The variation could not be logically attributed to the manufacture of the prisms.

Due to limited concrete mixer capacity the concrete prisms for mixtures 5, 6 and 7 had been made in a number of different but similar batches. One prism from each batch had then been assigned randomly to each laboratory. An analysis was done on the mean expansions for each batch. No significant differences in mean expansion were found from batch to batch. Two different sizes of concrete prisms had been made, depending on each participating laboratories measuring equipment (75 x 100x 405 mm and 75 x 75 x 400 mm). The two different sizes of prisms did not show significant and consistent differences in expansion.

In the analysis of variance only extreme outliers were excluded from the calculation since there was no obvious physical reason to consider the results, reported by labs F, I and J, as faulty. This, together with the small number of laboratories resulted in rather high standard deviations compared with mixtures 1 - 4 (Figures 6 and 7). This was surprising, since removing the variations caused by prism manufacture should have reduced variation.

An analysis was also done for the range in values obtained with three prisms of each material in a single laboratory (similar to that done for Parts 1 and 2). The average coefficient of variation for expansion greater than 0.02% was 19% compared with 12% obtained in Parts 1 and 2. The pooled standard deviation for expansion values less than 0.02% was about twice that obtained in Part 1 and 2.

The data obtained in Part 3 were not used for formulating any statement about precision. The results do show, however, that in this case, the variation caused by mixing the concrete and making the prisms was rather small compared with the variation that could be attributed to individual laboratories' measuring techniques or storage conditions or both. The wider variance compared to data from Parts 1 and 2 was probably due to the rather small number of laboratories and the inclusion of three laboratories out of seven that had no previous experience with this test procedure.

DISCUSSION

A comparison of the data obtained for mixtures 2 and 4, made with the same coarse aggregate, is interesting. Mixture 2 was made by individual laboratories using their own mixture proportions, fine aggregate and cement. In mixture 4, the proportions were specified and the fine aggregate and cement supplied by the co-ordinating laboratory. The pooled standard deviations for mixtures 2 and 4 were about the same (0.0043% and 0.0050%) and the average coefficients of variation were similar (27.5% and 25.0%). There was no significant improvement in precision by a more strict definition of the mixture proportions or material properties than allowed by the current test procedure.

The range in coarse aggregate/cement ratio (by mass) used by the various laboratories for mixture 2 was 3.14 to 3.63 (mean 3.43). In mixture 4, the ratio was defined as 3.51. Expansion of alkali-carbonate reactive aggregate is strongly correlated with cement alkali content. Those mixtures with the lowest coarse aggregate:cement ratio or highest amount of alkali per unit mass of coarse aggregate would have been expected to give the most expansion. Such was not the case, there was an apparently random relationship between coarse aggregate: cement ratio and expansion. The differences in expansion to be expected due to alkali load per unit mass of coarse aggregate must have been masked by other factors.

Figure 8 shows that there was considerable laboratory bias. A laboratory which obtained high (or low) expansion with mixture 3 generally obtained high (or low) results with mixture 7 even though the mixture 7 prisms had been made by the co-ordinating laboratory. Similar laboratory bias was also observed for the mildly expansive aggregate. This bias can be attributed to varying conditions between the laboratories. These variations must be caused by the storage conditions or measuring techniques or both.

One laboratory conducted an independent investigation of the effect of storage conditions on expansion (Figure 9). Wrapping prisms in plastic or placing them in a closed container resulted in a 300% increase in expansion at 1 year compared to uncovered storage in the humid room. This difference may be caused by leaching of alkalies by continuous exposure to moisture in an uncovered condition. Slight variations in the amount of free moisture falling or condensing on the prisms may have significant effects on the leaching of alkalies from the concrete and subsequent expansion. This would account for the wide variation found between the various laboratories. These laboratories which obtained high amounts of expansion may have had small amounts of free moisture in the humid room. Those laboratories with low values may have had high amounts of free moisture with considerable leaching of alkalies and reduced expansion.

An alternative explanation for the wide variation found under different storage conditions is that prisms stored in the moist room were insufficiently wet. This may have been the case with laboratory J. In laboratory A, the prisms were inspected frequently and always found to be wet, yet this laboratory reported results below the mean in nearly every mixture after one year. It is hard to see how the prisms could have been made wetter and hence obtain greater expansion.

Another purpose of this study was to gain data on appropriate expansion limits by using aggregates of known performance. Table 1 and Figures 10 and 11 show the field performance of these aggregates. Figure 1 shows that the highly expansive aggregate exceeded the 1977 CSA requirement at 84 days (CAN3-A23.1-M77). The mildly expansive aggregate which causes cracking of concrete in a moist environment met the 1977 requirement. The cement aggregate reactivity subcommittee of the C.S.A. cement committee (C.S.A.-A5) has recommended the following limits for the concrete prisms expansion test: For concrete exposed to a moist environment with or without exposure to de-icing salt, the maximum expansion at 84 days should not exceed 0.01% or failing that a maximum expansion of 0.025% at 1 year. At a cement alkali content of 1.0% Na_2O, the mildly expansive aggregate would have been accepted by two laboratories at 84 days. At 1 year, all laboratories obtained expansions equal to or greater than the requirement (Table 3, Figure 3). When the alkali level was increased to 1.1% in mixture 4, all but one laboratory, probably in error, obtained expansion greater than the requirement (Table 5, Figure 5). The new limits will ensure that given the wide multi-laboratory variation, most laboratories should identify this mildly expansive aggregate.

What about unnecessary rejection? For the non-expansive aggregate, three laboratories obtained expansion greater than 0.01% at 84 days (Table 2). After 1 year, two laboratories obtained expansion values that met or exceeded 0.025%. Clearly, there is need to test aggregate of known expansive properties and performance at the same time as an unknown aggregate is tested. This is common practice in many laboratories but is not a requirement of the test procedure.

CONCLUSIONS

1. For expansion less than 0.014%, results of two properly conducted tests in different laboratories, on the same aggregate, should not differ from each other by more than 0.009%. For expansion greater than 0.014%, the results should not differ by more than 65% of their average.

2. For expansion less than 0.02%, the range (difference between highest and lowest) of three individual prisms measurements used in calculating a test result should not exceed 0.008%. For expansion greater than 0.02%, the range should not exceed 40% of the average of the three.

3. There is considerable between laboratory bias in this test. The major source of this variation is thought to be the conditions of moist storage used in the testing.

4. A maximum expansion of 0.01% at 84 days or failing that, 0.025% at 1 year appears satisfactory. These values will separate aggregate that causes cracking in moist environments from aggregate that does not.

RECOMMENDATIONS

Further study should be conducted to determine the effect of storage conditions on expansion and on the variation of this test.

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Level in Quarry	Use in this Study	Los Angeles Abrasion and Impact Loss Percent	$MgSO_4$ Loss Percent	Absorption Percent	Relative Density	Field Performance in Portland Cement Concrete
1st Lift 0-9.2 m	Mix 1 and 5	24	8	0.43	2.69	Satisfactory for 30 years, non-expansive
3rd Lift 17.4-22.9 m	Mix 2, 4, and 6	22	6	0.37	2.72	Causes cracking in wet environment within 5 years, mildly expansive
4th Lift 22.9-28.1 m	Mix 3 and 7	18	6	0.57	2.72	Causes cracking and excessive expansion within 3 years, highly expansive

TABLE 1: COARSE AGGREGATE TEST RESULTS AND FIELD PERFORMANCE

TABLE 2: Expansion Data for Mix No. 1 - Non-Reactive Limestone

LABORATORY IDENTIFICATION		AVERAGE EXPANSION IN PERCENT						
		28 days	56 days	84 days	112 days	168 days	275 days	1 year
A		0.0050	0.0060	0.0110	0.0110	0.0110	0.0080	0.0080
B		0.0023	0.0030	0.0050	0.0063	0.0080	0.0117	0.0107
C	1	0.0023	0.0007	0.0007	-	0.0050	0.0087	0.0013
D		0.0023	0.0051	0.0051	0.0068	0.0086	-	0.0100
E		0.0047	0.0040	0.0073	0.0087	0.0057	0.0113	0.0110
F	2	0.0078	0.0078	0.0078	0.0107	0.0131	-	0.0146
G		0.0049	0.0166	0.0202	0.0218	0.0266	0.0397	0.0497
H		0.0137	0.0167	0.0173	0.0170	0.0187	0.0207	0.0227
I		0.0010	-0.0013	-0.0050	0.0073	-0.0110	-	-0.0033
J		-0.0013	0.0000	0.0010	0.0003	0.0070	-	0.0250
K		-0.0007	0.0058	0.0076	0.0076	0.0088	0.0091	0.0091
L		0.0050	0.0050	0.0066	0.0067	0.0100	0.0100	0.0100
OUTLIERS		H	G,H,I	G,H,I	G,H	G,H,I		G,H,I,J
Mean		0.0030	0.0042	0.0058	0.0073	0.0086		0.0092
Std. Dev.		0.0027	0.0025	0.0033	0.0031	0.0026		0.0037
Coef. Var.		90.0	59.5	56.9	42.5	30.2		40.2

NOTES:

1. *56 day actually 45, 84 day actually 90, 168 day actually 180, 275 day actually 270, 365 day actually 360.*

2. *28 day actually 30, 56 day actually 60, 84 day actually 90, 112 day actually 120, 168 day actually 180, 365 day actually 360.*

TABLE 3: Expansion Data for Mix No. 2 - Mildly Reactive Dolomitic Limestone

LABORATORY IDENTIFICATION		AVERAGE EXPANSION IN PERCENT						
		28 days	56 days	84 days	112 days	168 days	275 days	1 year
A		0.0110	0.0140	0.0196	0.0217	0.0223	0.0320	0.0290
B		0.0057	0.0100	0.0130	0.0153	0.0190	0.0243	0.0250
C	1	0.0053	0.0100	0.0123	-	0.0263	0.0300	0.0307
D		0.0070	0.0124	0.0126	0.0156	0.0189	-	0.0279
E		0.0083	0.0110	0.0150	0.0207	0.0163	0.0240	0.0257
F	2	0.0146	0.0170	0.0190	0.0219	0.0306	-	0.0403
G		0.0093	0.0178	0.0202	0.0201	0.0183	0.0314	0.0347
H		0.0073	0.0130	0.0157	0.0170	0.0197	0.0247	0.0280
I		0.0047	0.0050	0.0120	0.0157	0.0083	-	0.0083
J		0.0020	0.0046	0.0070	0.0077	0.0167	-	0.0350
K		0.0082	0.0210	0.0220	0.0218	0.0240	0.0247	0.0301
L		0.0050	0.0116	0.0150	0.0150	0.0183	0.0233	0.0250
OUTLIERS		F				I		I
Mean		0.0067	0.0123	0.0153	0.0175	0.0210		0.0301
Std. Dev.		0.0025	0.0048	0.0043	0.0043	0.0044		0.0048
Coef. Var.		37.3	39.0	28.1	24.6	21.0		16.0

NOTES:

1. *56 day actually 45, 84 day actually 90, 168 day actually 180, 275 day actually 270, 365 day actually 360.*

2. *28 day actually 30, 56 day actually 60, 84 day actually 90, 112 day actually 120, 168 day actually 180, 365 day actually 360.*

TABLE 4: Expansion Data for Mix No. 3 - Highly Reactive Dolomitic Limestone

LABORATORY IDENTIFICATION		AVERAGE EXPANSION IN PERCENT						
		28 days	56 days	84 days	112 days	168 days	275 days	1 year
A		0.0170	0.0200	0.0280	0.0310	0.0390	0.0600	0.0696
B		0.0137	0.0217	0.0263	0.0347	0.0433	0.0577	0.0660
C	1	0.0157	0.0237	0.0397	-	0.0783	0.1017	0.1267
D		0.0147	0.0248	0.0309	0.0388	0.0535	-	0.0950
E		0.0143	0.0207	0.0277	0.0370	0.0377	0.0523	0.0573
F	2	0.0272	0.0423	0.0559	0.0680	0.1040	-	0.2070
G		0.0090	0.0162	0.0268	0.0309	0.0566	0.0634	0.0704
H	3	0.0130	0.0215	0.0295	0.0355	0.0490	0.0640	0.0760
I		0.0237	0.0283	0.0377	0.0470	0.0527	-	0.0920
J		0.0037	0.0060	0.0090	0.0090	0.0187	-	0.0423
K		0.0106	0.0210	0.0239	0.0259	0.0356	0.0462	0.0554
L		0.0150	0.0225	0.0300	0.0383	0.0533	0.0750	0.0933
OUTLIERS		J, F	J, F	J, F	J, F	J, F		F
Mean		0.0147	0.0220	0.0301	0.0355	0.0499		0.0767
Std. Dev.		0.0040	0.0032	0.0050	0.0060	0.0125		0.0236
Coef. Var.		27.2	14.6	16.6	16.9	25.1		30.8

NOTES:

1. *56 day actually 45, 84 day actually 90, 168 day actually 180, 275 day actually 270, 365 day actually 360.*

2. *28 day actually 30, 56 day actually 60, 84 day actually 90, 112 day actually 120, 168 day actually 180, 365 day actually 360.*

3. *Average of 2 prisms; 1 prism was defective.*

TABLE 5: *Expansion Data for Mix No. 4 - Mildly Reactive Dolomitic Limestone All Made with Same Cement, Fine Aggregate and Mix Proportions*

LABORATORY IDENTIFICATION		AVERAGE EXPANSION IN PERCENT						
		28 days	56 days	84 days	112 days	168 days	275 days	1 year
A		0.0090	0.0110	0.0170	0.0170	0.0180	0.0273	0.0310
B		0.0060	0.0103	0.0130	0.0180	0.0220	0.0273	0.0300
C	1	0.0097	0.0090	0.0200	-	0.0220	0.0280	0.0317
D		0.0103	0.0149	0.0168	0.0196	0.0237	-	0.0314
E		0.0110	0.0150	0.0193	0.0203	0.0213	0.0307	0.0343
F	2	0.0141	0.0180	0.0272	0.0267	0.0350	-	0.0418
G	3	0.0042	0.0123	0.0168	0.0178	0.0174	0.0348	0.0280
H		0.0127	0.0213	0.0270	0.0290	0.0357	0.0420	0.0470
I		0.0050	0.0023	0.0036	0.0083	0.0000	-	0.0190
J		0.0067	0.0130	0.0157	0.0120	0.0250	-	0.0473
K		0.0126	0.0158	0.0197	0.0216	0.0236	0.0307	0.0355
L		0.0100	0.0150	0.0192	0.0217	0.0233	0.0300	0.0333
OUTLIERS			I	I	I	I		I
Mean		0.0093	0.0142	0.0192	0.0204	0.0243		0.0356
Std. Dev.		0.0032	0.0036	0.0044	0.0049	0.0060		0.0068
Coef. Var.		34.4	25.4	22.9	24.0	24.7		19.1

NOTES:

1. *56 day actually 45, 84 day actually 90, 168 day actually 180, 275 day actually 270, 365 day actually 360.*

2. *28 day actually 30, 56 day actually 60, 84 day actually 90, 112 day actually 120, 168 day actually 180, 365 day actually 360.*

3. *Lab G did not use same cement as other labs.*

TABLE 6: Expansion Data for Mix No. 5 - Non-Reactive Limestone
All Prisms Made by Lab A.

LABORATORY IDENTIFICATION		AVERAGE EXPANSION IN PERCENT						
		28 days	56 days	84 days	112 days	168 days	275 days	1 year
A	1	0.0010	0.0010	0.0040	0.0060	0.0060	0.0080	0.0080
A	2	0.0093	0.0093	0.0140	0.0117	0.0140	0.0070	0.0070
B	1,3	0.0010	0.0026	0.0020	0.0057	0.0083	0.0087	0.0090
C	2,4	0.0013	-	0.0017	-	0.0053	0.0020	0.0050
D	1	0.0042	0.0047	0.0070	0.0067	0.0082	-	0.0095
F	2,5	0.0083	0.0083	0.0130	0.0130	0.0130	-	0.0139
I	2	-0.0143	-0.0070	-0.0060	0.0060	0.0000	-	0.0156
J	1,6	0.0080	0.0103	0.0123	0.0143	0.0213	0.0267	0.0267
OUTLIERS		I	I	I		J		J
Mean		0.0047	0.0060	0.0077	0.0091	0.0078		0.0097
Std. Dev.		0.0037	0.0038	0.0054	0.0038	0.0048		0.0038
Coef. Var.		78.7	63.3	70.1	41.7	61.5		39.2

NOTES:

1. *75 x 75 x 400 prisms*
2. *75 x 100 x 405 mm prisms*
3. *Initial length after 28 days storage*
4. *84 day actually 90, 168 day actually 180, 275 day actually 270, 365 day actually 360.*
5. *28 day actually 30, 56 day actually 60, 112 day actually 120, 168 day actually 180, 365 day actually 360.*
6. *84 day data obtained by interpolating 56 and 112 day data.*

TABLE 7: Expansion Data for Mix No. 6 - Mildly Reactive Dolomitic Limestone All Prisms Made by Lab A.

LABORATORY IDENTIFICATION		AVERAGE EXPANSION IN PERCENT						
		28 days	56 days	84 days	112 days	168 days	275 days	1 year
A	1	0.0060	0.0070	0.0090	0.0167	0.0157	0.0253	0.0270
A	2	0.0063	0.0083	0.0083	0.0153	0.0153	0.0157	0.0177
B	1, 3	0.0016	0.0030	0.0073	0.0100	0.0140	0.0160	0.0163
C	2, 4	0.0066	-	0.0110	-	0.0177	0.0200	0.0257
D	1	0.0062	0.0085	0.0122	0.0134	0.0169	-	0.0256
F	2, 5	0.0111	0.0111	0.0157	0.0167	0.0200	-	0.0306
I	2	0.0060	0.0140	0.0060	0.0153	0.0027	-	0.0317
J	1, 6	0.0100	0.0173	0.0205	0.0237	0.0283	0.0390	0.0397
OUTLIERS						I		
Mean		0.0067	0.0099	0.0113	0.0159	0.0183		0.0268
Std. Dev.		0.0029	0.0047	0.0048	0.0042	0.0048		0.0076
Coef. Var.		43.3	47.5	42.5	26.4	26.2		28.4

NOTES:

1. *75 x 75 x 400 prisms*
2. *75 x 100 x 405 mm prisms*
3. *Initial length after 28 days storage*
4. *84 day actually 90, 168 day actually 180, 275 day actually 270, 365 day actually 360.*
5. *28 day actually 30, 56 day actually 60, 112 day actually 120, 168 day actually 180, 365 day actually 360.*
6. *84 day data obtained by interpolating 56 and 112 day data.*

TABLE 8: *Expansion Data for Mix No. 7 - Highly Reactive Dolomitic Limestone All Prisms Made by Lab A.*

LABORATORY IDENTIFICATION		AVERAGE EXPANSION IN PERCENT						
		28 days	56 days	84 days	112 days	168 days	275 days	1 year
A	1	0.0086	0.0130	0.0260	0.0340	0.0370	0.0607	0.0740
A	2	0.0093	0.0143	0.0143	0.0430	0.0307	0.0520	0.0567
B	1, 3	0.0078	0.0183	0.0217	0.0277	0.0427	0.0517	0.0613
C	2, 4	0.0143	-	0.0277	-	0.0483	0.0603	0.0740
D	1	0.0142	0.0217	0.0293	0.0341	0.0490	-	0.0814
F	2, 5	0.0259	0.0278	0.0343	0.0463	0.0713	-	0.1416
I	2	0.0000	0.0023	0.0047	0.0270	0.0423	-	0.1070
J	1, 6	0.0113	0.0187	0.0262	0.0337	0.0450	0.0607	0.0650
OUTLIERS		I	I	I				F
Mean		0.0130	0.0190	0.0256	0.0351	0.0458		0.0742
Std. Dev.		0.0063	0.0054	0.0063	0.0072	0.0119		0.0168
Coef. Var.		48.5	28.4	24.6	20.5	26.0		22.6

NOTES:

1. *75 x 75 x 400 prisms*
2. *75 x 100 x 405 mm prisms*
3. *Initial length after 28 days storage*
4. *84 day actually 90, 168 day actually 180, 275 day actually 270, 365 day actually 360.*
5. *28 day actually 30, 56 day actually 60, 112 day actually 120, 168 day actually 180, 365 day actually 360.*
6. *84 day data obtained by interpolating 56 and 112 day data.*

FIGURE 1 MEAN CONCRETE PRISM EXPANSION OF ALL MIXES (OUTLIERS EXCLUDED)

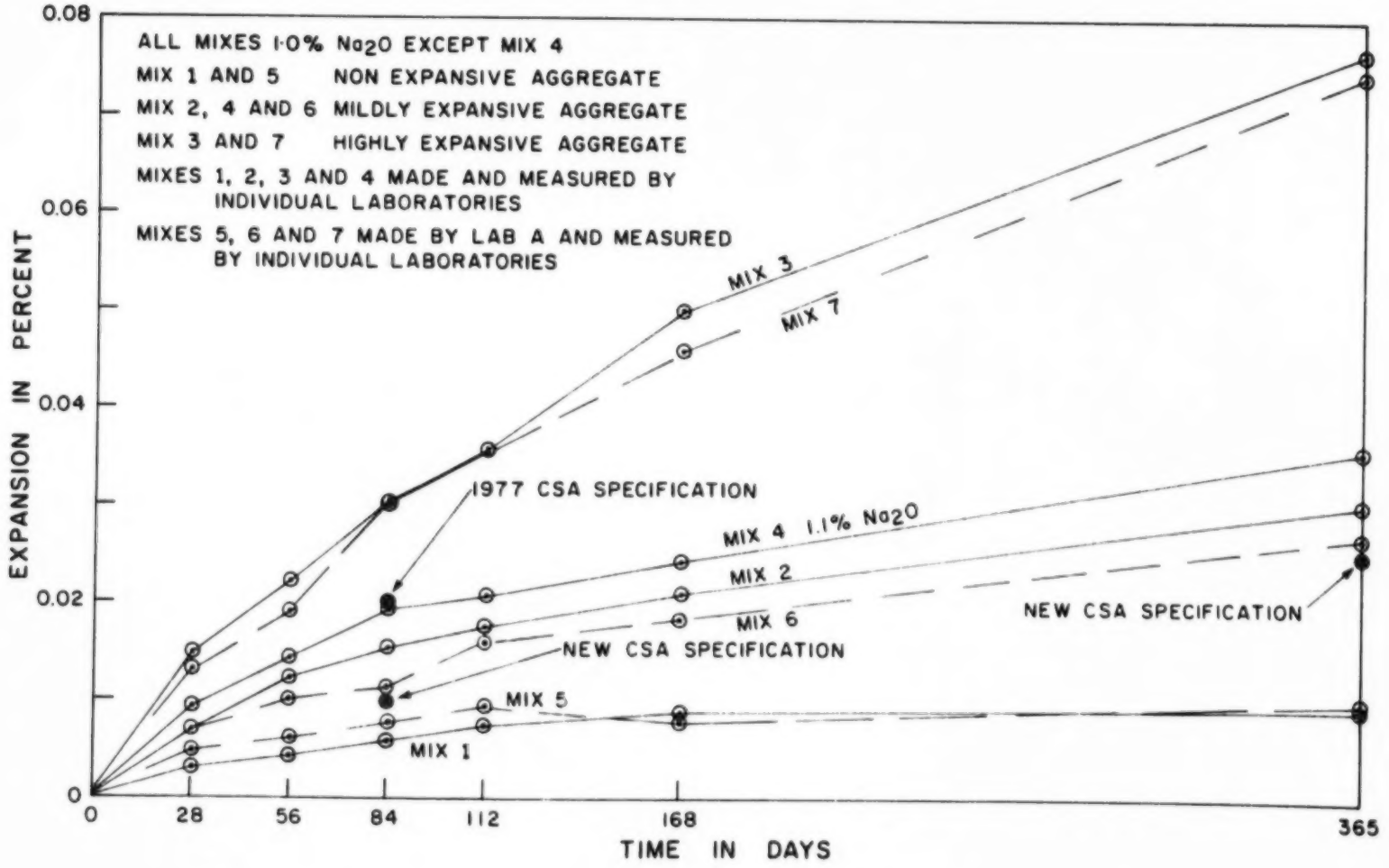


FIGURE 2 SCATTER DIAGRAM FOR MIX 2 (1.0% Na_2O) AND MIX 4 (1.1% Na_2O) MILDLY EXPANSIVE AGGREGATE

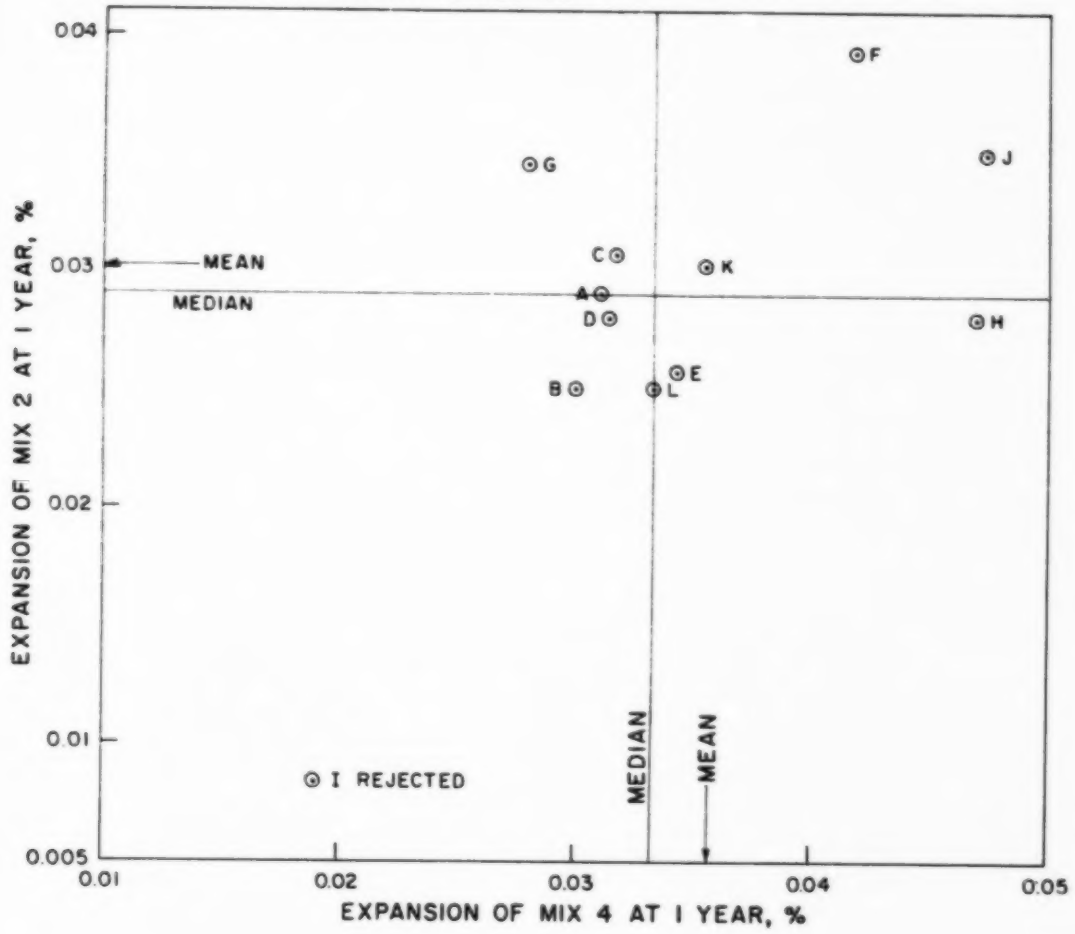


FIGURE 3 EXPANSION AGAINST TIME FOR MIX 2 (MILDLY EXPANSIVE) SHOWING MEAN, RANGE AND OUTLIERS TO THE POPULATION.

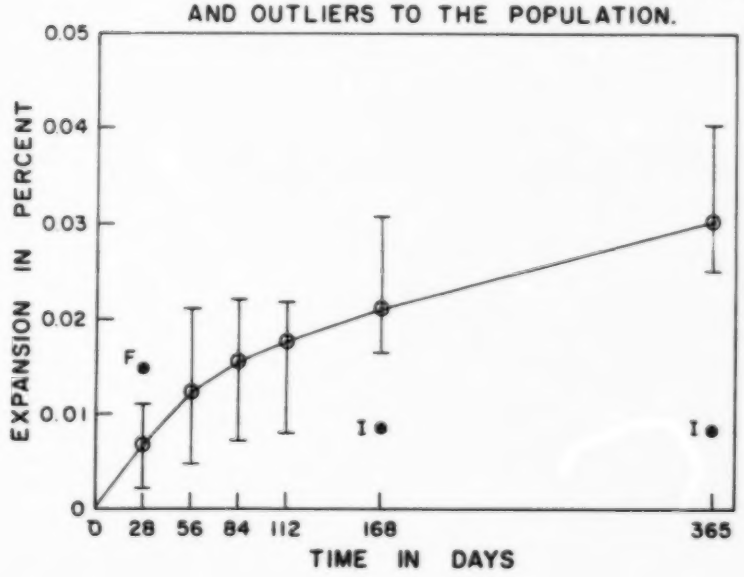


FIGURE 4 EXPANSION AGAINST TIME FOR MIX 3 (HIGHLY EXPANSIVE) SHOWING MEAN, RANGE AND OUTLIERS TO THE POPULATION

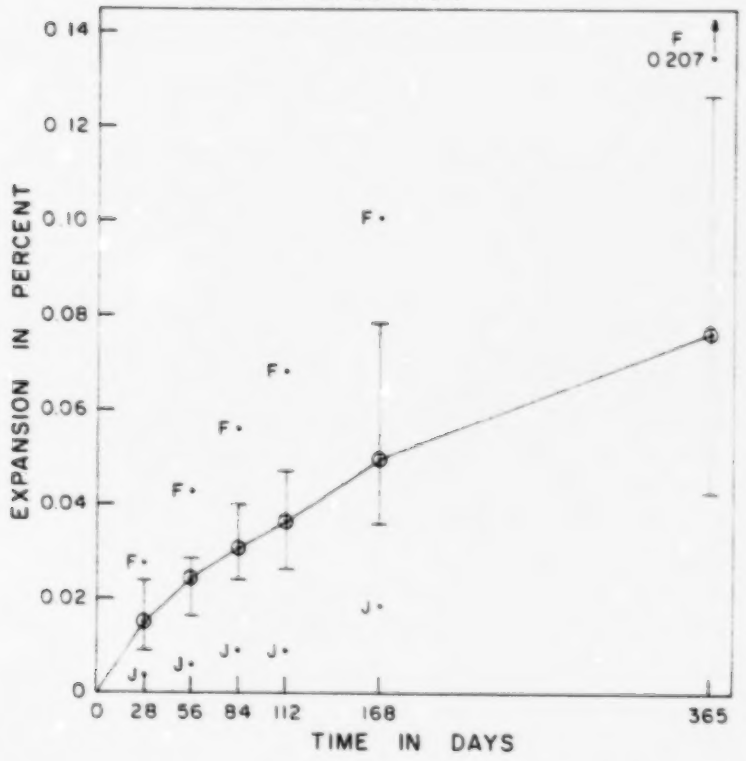


FIGURE 5 EXPANSION AGAINST TIME FOR MIX 4 (MILDLY EXPANSIVE) AT 1.1% Na_2O, SHOWING MEAN, RANGE AND OUTLIERS TO THE POPULATION

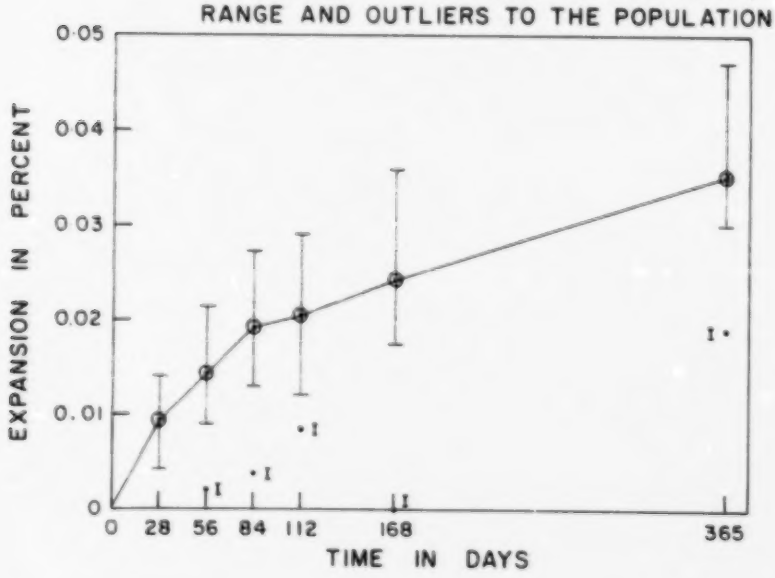


FIGURE 6 MULTILABORATORY COEFFICENT OF VARIATION AGAINST MEAN EXPANSION (OUTLIERS EXCLUDED)

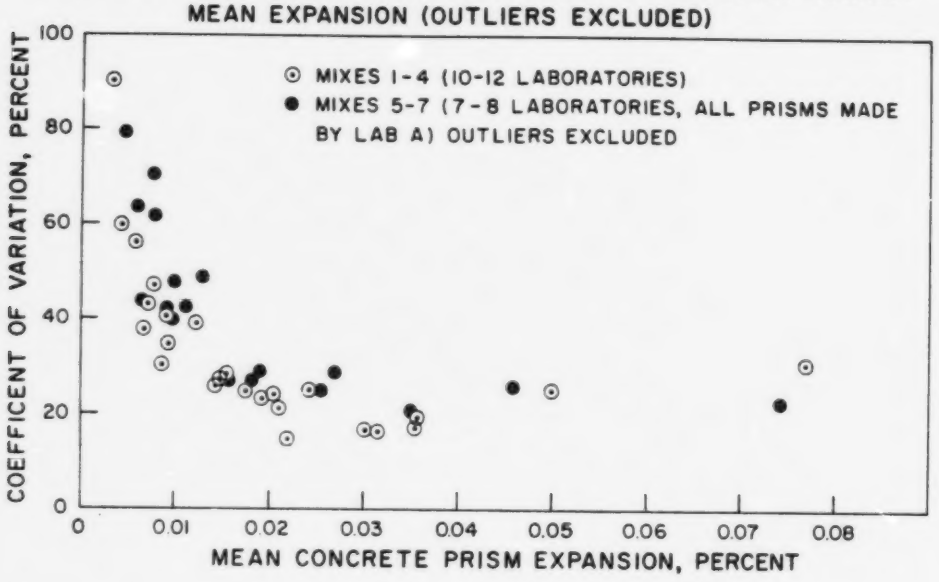


FIGURE 7 MULTILABORATORY STANDARD DEVIATION AGAINST MEAN EXPANSION (OUTLIERS EXCLUDED)

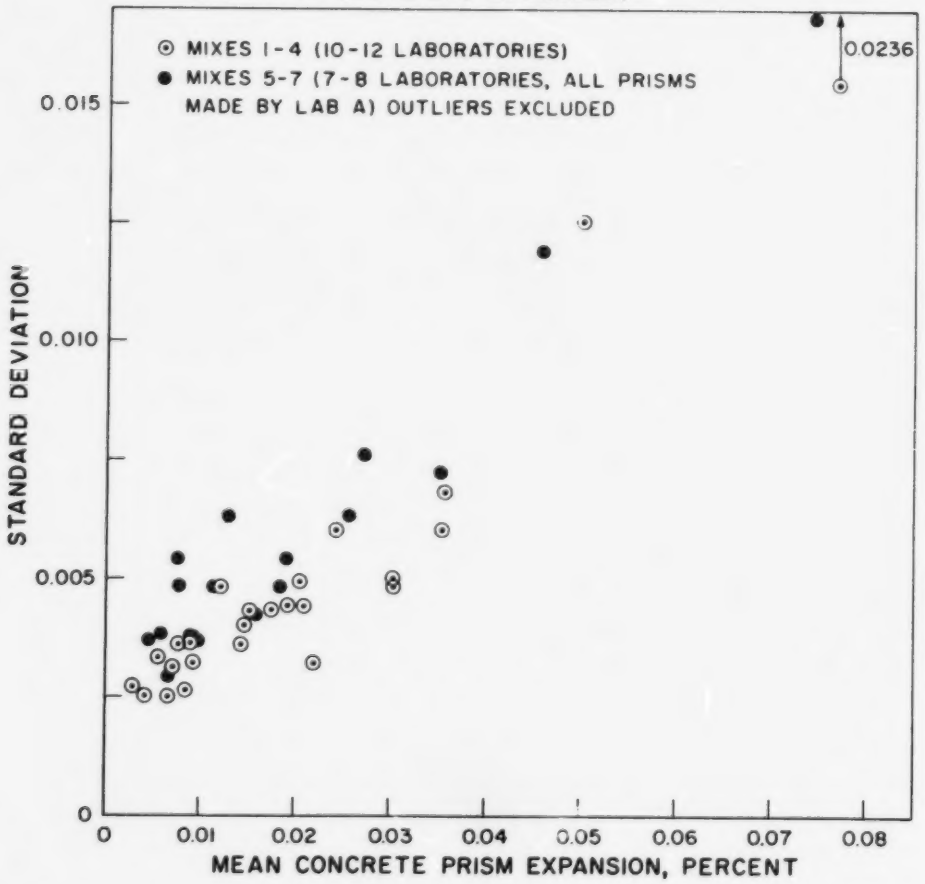


FIGURE 8 SCATTER DIAGRAM FOR MIX 3 (PRISMS MADE & MEASURED BY EACH LABORATORY) AND MIX 7 (PRISMS MADE BY CENTRAL LABORATORY BUT MEASURED BY INDIVIDUAL LABORATORIES). HIGHLY EXPANSIVE AGGREGATE.

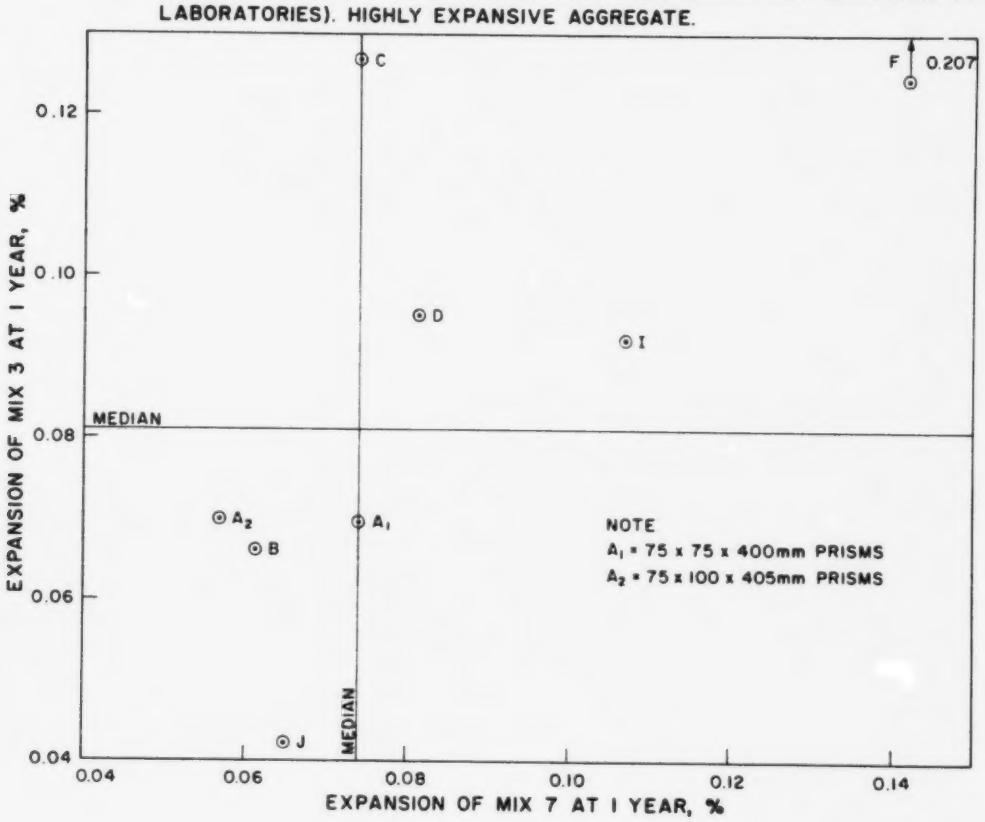
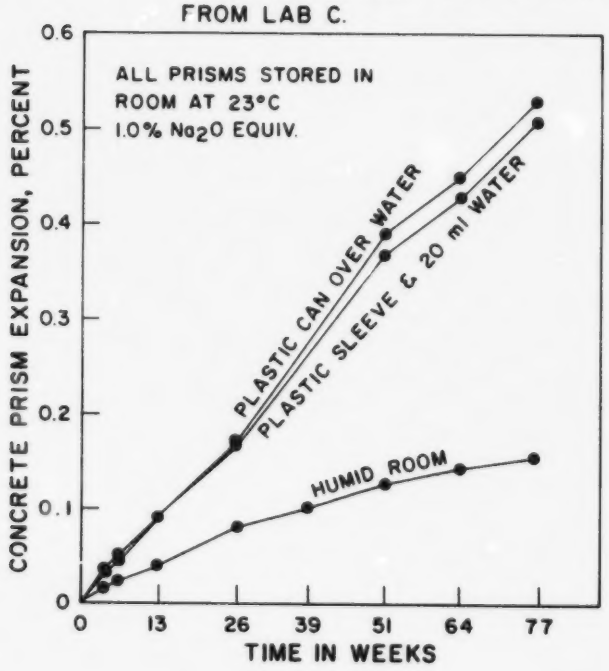


FIGURE 9 EFFECT OF DIFFERENT STORAGE CONDITIONS ON EXPANSION OF CONCRETE PRISMS (MIX 3). DATA FROM LAB C.



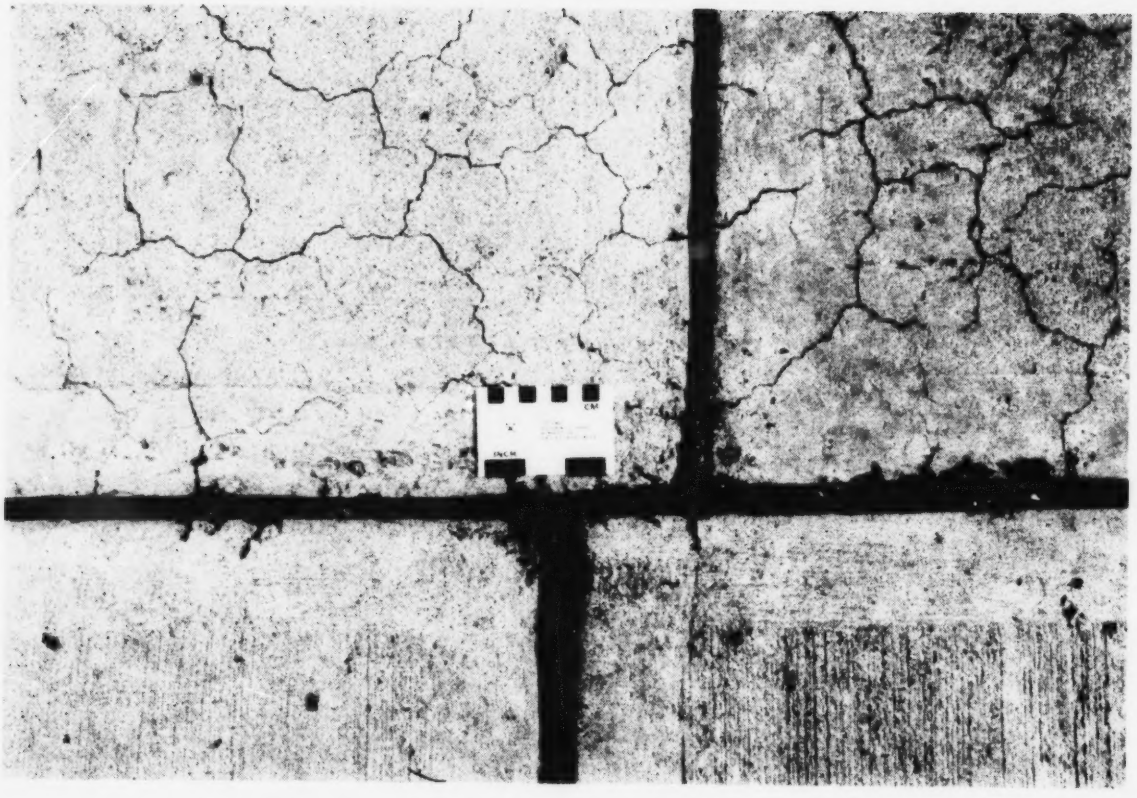


FIGURE 10: **Alkali-carbonate expansive concrete in upper part of photo has moved 9 cm to the right, compared with non-reactive concrete in lower part of photo. Expansion in this example was measured as 1.2% in three years. This aggregate was used in Mixtures 3 and 7.**

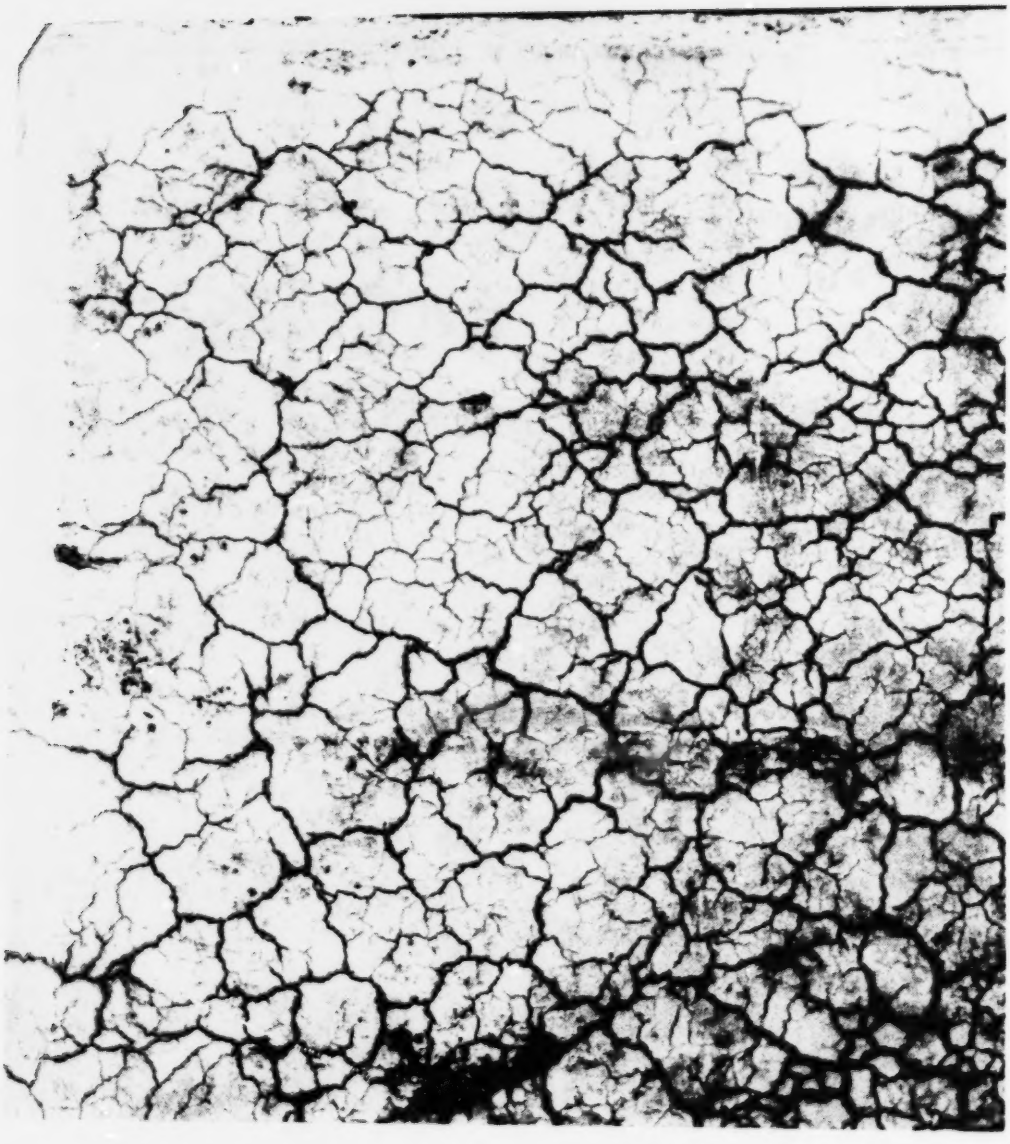


FIGURE 11: **Retaining wall built with coarse aggregate used in Mixtures 2, 4, and 6. Appearance after about 7 years.**

APPENDIX

EQUIPMENT USED BY LABORATORIES

CONCRETE MIXTURE PROPORTION DATA

TABLE 1: SUMMARY OF EQUIPMENT USED BY VARIOUS LABORATORIES

LABORATORY IDENTIFICATION	A	B	C	D	E	F	G	H	I	J	K	L
Size of prism in mm	400 75 75	387 102 76	405 100 77	406 101 76	286 76 76	400 100 75	407 102 75	286 75 75 ±2.5	406 102 77	400 75 75	405 100 75	355 75 75
Effective length of prism (internal distance between gauge studs) in mm	342	358	363	360	254	343	357	254	338	340	350	305
Horizontal (H) or vertical (V) measuring device? Please enclose a sketch or photograph.	V	H	V	H	V	V	V	V	V	V	V	V
Dial Gauge (D) or Micrometer (M) used?	D	D	D	M	D	D	D	D	D	D	D	D
Sensitivity	0.01 mm	0.0001 in.	0.0001 in.	0.0001 in.	0.0025 mm	0.01 mm	0.01 mm	0.0001 in.	0.0001 in.	0.0001 in.	0.0001 in.	0.0001 in.
Do you rotate prism prior to making measurement?	No	No	No	No	Yes	No	No	Yes	Yes	Yes	No	Yes
Do you take minimum reading as length?	No	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes
Moist storage facility average temperature °C	23.3°C	23°C	23°C	24°C	23°C	23°C	23°C	23°C	21-25°C	23°C	21°C	23°C
range in temperature	21-26°C	±2°C	±2°C	22-25°C	±1.7°C	±1°C	±2°C	±1.7°C		21.3-24.7°C	18-22°C	21.5-24.5°C
NOTES & COMMENTS: TYPE OF MEASURING DEVICE												
Swenson Type	Yes	-	Yes	-	-	Yes		-	Yes	-	Yes	-
Mortar Bar Type	-	-	-	-	-	-		Yes	-	Yes	-	Yes
Other	-	Yes	-	Yes	Yes	-		-	-	-	-	-

TABLE 2: CONCRETE AND CEMENT PROPERTY DATA FOR MIX 1

LABORATORY IDENTIFICATION	A	B	C	D	E	F	G	H	I	J	K	L
Air content when plastic A23.2-4C	2.2	1.5	-	3.0	1.5	1.4	3.2	2.7	1.5	1.9	1.5	2.0
Slump A23.2-5C	85	70	76	75	74	90	90	50	95	75	85	80
Effective w/c ratio	0.536	0.55	0.50	0.55	0.58	0.544	0.597	0.62	0.573	0.58	0.58	0.55
Compressive Strength at 28 days A23.2-9C — 7 day	24.4											28.0
Compressive Strength at 28 days A23.2-9C	32.4	35.4	34.3	29.9	36.4	31.2	28.1	27.7	37.0	34.6	35.3	33.4
Compressive Strength at 28 days A23.2-9C — 6 month							31.2					
Concrete Proportions												
coarse aggregate (kg)	43.5	34.5	37.5	45.3	23.0	29.2	40.8	24.2	44.5	43.5	26.4	40.9
fine aggregate (kg)	33.6	24.9	21.0	34.5	17.0	22.2	35.2	22.6	33.5	33.5	24.0	34.0
cement (kg)	12.4	9.5	10.3	12.9	6.58	8.4	12.4	8.0	12.4	12.4	8.4	12.5
total water (kg)	7.15	5.3	5.20	7.08	-	4.57	7.40	5.2	7.10	7.2	5.46	7.40
Cement Properties												
% Na_2O	0.57		0.33	0.42	0.24	0.58	0.22	0.29	0.21	0.33	0.22	0.28
% K_2O	0.61		1.04	0.99	1.15	0.54	0.94	0.85	1.25	1.04	0.90	0.71
% equivalent Na_2O	0.97		1.01	1.07	1.00	0.94	0.84	0.85	1.03	1.01	0.81	0.75
Alkali content of the mix as % equivalent Na_2O by mass of cement (Paragraph 4.1)	1.00		1.01	1.07	1.00	1.00	1.00	1.00	1.03	1.01	1.00	1.00

TABLE 3: CONCRETE AND CEMENT PROPERTY DATA FOR MIX 2

LABORATORY IDENTIFICATION	A	B	C	D	E	F	G	H	I	J	K	L
Air content when plastic A23.2-4C	1.9	1.8	-	3.3	1.6	1.7	3.4	2.7	1.75	2.0	1.5	2.1
Slump A23.2-5C	75	70	76	70	71	80	90	80	95	85	89	80
Effective w/c ratio	0.536	0.55	0.50	0.55	0.62	0.535	0.597	0.61	0.574	0.60	0.58	0.56
Compressive Strength at 28 days A23.2-9C — 7 day	23.2											26.5
Compressive Strength at 28 days A23.2-9C	31.2	34.0	34.4	31.0	38.6	31.6	27.2	27.7	36.3	33.8	28.1	31.2
Compressive Strength at 28 days A23.2-9C — 6 month							30.5					
Concrete Proportions												
coarse aggregate (kg)	43.4	34.5	37.5	45.3	23.1	29.2	40.8	24.4	44.5	43.5	26.38	40.2
fine aggregate (kg)	34.0	24.9	21.0	34.5	17.0	22.2	35.6	22.6	33.5	33.5	24.02	34.9
cement (kg)	12.4	9.5	10.3	13.2	6.58	8.4	12.4	8.0	12.4	12.4	8.37	12.4
total water (kg)	7.15	5.3	5.17	7.20	-	4.49	7.40	5.2	7.12	7.4	5.46	7.55
Cement Properties												
% Na_2O	0.57		0.33	0.42	0.24	0.58	0.22	0.29	0.21	0.33	0.22	0.28
% K_2O	0.61		1.04	0.99	1.15	0.54	0.94	0.85	1.25	1.04	0.90	0.71
% equivalent Na_2O	0.97		1.01	1.07	1.00	0.94	0.84	0.85	1.03	1.01	0.81	0.75
Alkali content of the mix as % equivalent Na_2O by mass of cement (Paragraph 4.1)	1.00		1.01	1.07	1.00	1.00	1.00	1.00	1.03	1.01	1.00	1.00

TABLE 4: CONCRETE AND CEMENT PROPERTY DATA FOR MIX 3

LABORATORY IDENTIFICATION	A	B	C	D	E	F	G	H	I	J	K	L
Air content when plastic A23.2-4C	1.7	1.5	-	3.2	1.4	1.7	3.4	2.6	1.75	1.9	2.0	1.9
Slump A23.2-5C	85	83	76	85	71	80	80	60	90	90	75	90
Effective w/c ratio	0.548	0.55	0.50	0.52	0.64	0.549	0.597	0.61	0.575	0.58	0.58	0.57
Compressive Strength at 28 days in MPa A23.2-9C — 7 day	27.4											25.8
Compressive Strength at 28 days in MPa A23.2-9C — 28 day	35.1	32.8	33.15	30.1	35.5	31.8	29.3	28.8	36.2	34.0	31.0	30.4
Compressive Strength at 28 days in MPa A23.2-9C — 6 month							33.9					
Concrete Proportions												
coarse aggregate (kg)	44.3	34.5	37.5	45.3	23.2	29.2	40.8	24.4	44.5	43.5	26.4	40.4
fine aggregate (kg)	33.3	24.9	21.0	34.5	17.0	22.2	35.6	22.6	33.5	33.5	24.0	34.7
cement (kg)	12.4	9.5	10.3	13.2	6.58	8.4	12.4	8.0	12.4	12.4	8.4	12.3
total water (kg)	7.30	5.3	5.17	6.85	-	4.61	7.40	5.2	7.13	7.2	5.46	7.70
Cement Properties												
% Na_2O	0.57		0.33	0.42	0.24	0.58	0.22	0.29	0.21	0.33	0.22	0.28
% K_2O	0.61		1.04	0.99	1.15	0.54	0.94	0.85	1.25	1.04	0.90	0.71
% equivalent Na_2O	0.97		1.01	1.07	1.00	0.94	0.84	0.85	1.03	1.01	0.81	0.75
Alkali content of the mix as % equivalent Na_2O by mass of cement (Paragraph 4.1)	1.00		1.01	1.07	1.00	1.00	1.00	1.00	1.03	1.01	1.00	1.00

TABLE 5: CONCRETE AND CEMENT PROPERTY DATA FOR MIX 4

LABORATORY IDENTIFICATION	A	B	C	D	E	F	G	H	I	J	K	L
Air content when plastic A23.2-4C	3.0	2.5	-	2.4	1.5	2.5	2.2	2.3	1.75	2.1	2.5	2.2
Slump A23.2-5C	85	67	76	75	81	70	80	80	180	80	72	80
Effective w/c ratio	0.524	0.53	0.53	0.57	0.57	0.532	0.51	0.55	0.640	0.58	unknown	0.56
Compressive Strength at 28 days A23.2-9C — 7 day	23.5											25.0
28 day	33.6	30.9	34.4	31.2	33.6	32.7	38.4	33.2	31.9	34.5	34.6	32.4
Concrete Proportions												
coarse aggregate (kg)	43.5	24.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5
fine aggregate (kg)	33.5	18.9	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5
cement (kg)	12.4	7.0	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
total water (kg)	7.0	3.7	6.85	7.05	-	6.60	6.35	-	7.94	7.20	-	7.5
Cement Properties												
% Na_2O	0.49											
% K_2O	0.93	ALL LABORATORIES USED SAME CEMENT AND SAME FINE AGGREGATE										
% equivalent Na_2O	1.10											
Alkali content of the mix as % equivalent Na_2O by mass of cement (Paragraph 4.1)	1.10	1.10	1.10	1.10	1.10	1.10	1.05*	1.10	1.10	1.10	1.10	1.10

* Lab G lost cement, used cement with 0.35% Na_2O, 1.06% K_2O, 1.05% Na_2O equivalent

	MIX 5	MIX 6	MIX 7
Air content when plastic A23.2-4C	1.7 1.7 1.9	1.7 1.7 1.7	1.3 1.7 1.7
Slump A23.2-5C	85	75	80
Effective w/c ratio	0.556	0.548	0.560
Compressive Strength at 28 days MPa (total of 6 cylinders A23.2-9C	35.9 34.4 33.8	34.1 32.3 32.5	34.4 33.2 30.6
Mean	34.7	33.0	32.7
Concrete Proportions			
coarse aggregate (kg)	43.5	43.4	44.3
fine aggregate (kg)	33.6	34.0	33.3
cement (kg)	12.4	12.4	12.4
total water (kg)	7.40	7.30	7.45
Cement Properties			
% Na_2O	0.58	0.58	0.58
% K_2O	0.58	0.58	0.58
% equivalent Na_2O	0.96	0.96	0.96
Alkali content of the mix as % equivalent Na_2O by mass of cement (Paragraph 4.1)	1.0	1.0	1.0
NOTE: Each mix was made 3 times to give required quantities			

TABLE 6: CONCRETE AND CEMENT PROPERTY DATA FOR MIXES 5, 6, AND 7 (PRISMS SENT TO VARIOUS LABORATORIES)

A23.2-14A

Alkali-Aggregate Reaction

1. **Scope**

1.1 This Test Method covers the determination of the potential expansion of cement-aggregate combinations by measurement of the change in length of concrete prisms during storage in a moist room.

1.2 The test is suitable for the evaluation of coarse aggregate suspected to produce alkali-silica or alkali-carbonate reactions in concrete.

2. **Apparatus**

2.1 Specimens shall be cast into prismatic steel moulds not less than 75 mm × 75 mm × 350 mm and not more than 120 mm × 120 mm × 450 mm. All specimens in any test series shall be of the same nominal size.

2.2 Stainless steel studs not less than 5 mm in diameter × 35 mm in length and not more than 7 mm in diameter × 40 mm in length shall be cast in the test prism at the centre of each end.

2.3 The comparator used for the determination of length change shall be used in conjunction with a reference bar of the same length as the nominal length of the specimens and a dial gauge shall be marked in divisions not greater than 0.01 mm.

2.4 The moist room shall be such that the temperature shall be maintained at 23 ± 2°C and free water shall be present on the entire surface area of the specimens at all times.

3. **Test Specimens**

3.1 The test specimens shall be concrete prisms cast in the moulds specified in Clause 2.1. Three specimens shall constitute a test.

3.2 Two 150 mm × 300 mm test cylinders shall be made and cured as specified in CSA Test Method A23.2-3C, Making and Curing Concrete Compression and Flexural Test Specimens, and tested in compression at 28 days as specified in CSA Test Method A23.2-9C, Compressive Strength of Cylindrical Concrete Specimens.

4. **Materials**

4.1 Cement shall meet the requirements of Normal Portland cement (type 10) of CSA Standard CAN3-A5, Portland Cements. The alkali content of the cement shall be 0.9 ± 0.1 per cent, calculated as $Na_2O + 0.658\ K_2O$. Reagent grade sodium hydroxide (NaOH) shall be added to the concrete mix in such an amount that the alkali content of the mix, expressed as equivalents of Na_2O is 1 per cent by mass of cement.

Note: *Where cements with alkali content higher than 0.9 per cent, expressed as equivalent Na_2O, are encountered, the test should be carried out using the cement with the highest expected alkali content.*

4.2 Fine aggregate shall meet the requirements of CSA Standard CAN3-A23.1, Concrete Materials and Methods of Concrete Construction, and shall have a fineness modulus of 2.80 ± 0.1. Fine aggregate shall be non-reactive when tested in accordance with ASTM Standard C227, Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method).

4.3 The coarse aggregate under test shall be separated on 20 mm, 14 mm, 10 mm and 5 mm sieves and recombined taking equal portions by mass of the three sizes of material. Oversize and undersize material shall be discarded.

5. Concrete Mix Proportions

5.1 The concrete mix shall be proportioned to the following requirements:

Cement ..... 310 ± 3 kg/m³;
Slump ..... 80 ± 10 mm;
Air Content ..... not to exceed 3 per cent.

6. Preparation of Material

6.1 Fine and coarse aggregate shall be measured out in oven-dry condition, soaked in water for 24 hours and batched in the saturated condition.

6.2 All materials, including water, shall be at room temperature prior to batching.

7. Fabrication of Concrete Prisms

7.1 The prism mould, with the measuring studs in place, shall be filled with concrete and consolidated to ensure proper compaction.

7.2 After moulding and compaction any excess concrete shall be struck off with a wooden float and the surface of the specimens brought to a smooth finish.

7.3 Immediately after finishing, the specimens shall be covered with polyethelene sheet and placed in the moist room.

8. Demoulding and Storage of Concrete Prisms

8.1 The prisms shall be demoulded 23.5 ± 0.5 hours after moulding. During this procedure special care shall be taken to avoid damaging or disturbing the measuring studs.

8.2 Immediately after demoulding the specimens shall be immersed in water at a temperature of 23 ± 2°C for 30 ± 5 minutes.

8.3 Immediately upon removal from the water the specimens shall be measured for length.

8.4 After the length measurement has been taken the specimens shall be placed in the moist room for storage.

9. Length Change Measurements

9.1 The prisms shall be measured for length change after 7, 14, 28, 56, 84, 112, and 168 days of moist storage and at intervals of approximately 6 months thereafter.

9.2 Each time a prism is measured for length it shall be visually examined for cracks and surface deterioration.

10. Calculation of Length Change

10.1 The change in length of each specimen shall be based on the initial measurement.

10.2 The difference between the initial measurement and each succeeding measurement shall be calculated and expressed as a percentage of the initial length to the nearest 0.005 per cent.